

*Radiation in Explosions of Coal-gas and Air.*

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(Abstract.)

This paper contains the results of experiments on the radiation emitted by mixtures of coal-gas and air during explosion and subsequent cooling, carried out under the guidance of Prof. Hopkinson in the Engineering Laboratory at Cambridge. In the first part, measurements of the total radiation emitted by gaseous mixtures of various strengths and densities are given; and the second part consists of an investigation into the transparency and emissive power of the hot gaseous mixtures after explosion.

The gaseous mixtures were exploded in a plain cylindrical cast-iron vessel 30 cm. in diameter and 30 cm. in length, and were in all cases ignited by means of an electric spark in the centre of the vessel.

Into one of the end covers there was screwed a gunmetal tube which carried at its inner end a plate of diathermanous substance (a plate of fluorite was generally used), and behind it was placed a platinum bolometer with a blackened surface. The bolometer thus received all the radiation from the hot gaseous mixture which was transmitted through the plate of diathermanous substance. In order to measure the heat received by the bolometer its rise of electrical resistance was measured. The galvanometer, whose deflections were proportional to the rise of resistance of the bolometer, was of low period and carried a light concave mirror by means of which a spot of light was focussed on to a revolving photographic film rotating at a known speed, so that a continuous record of the rise of resistance of the bolometer, and therefore of the heat received by the bolometer, was obtained. At the same time and on the same film a continuous record of the pressure of the gaseous mixture was also taken by means of a Hopkinson optical indicator.

The following are the main results obtained from the experiments :—

*Part I.*—When mixtures of coal-gas and air of various strengths, at atmospheric density, are exploded in the vessel when its walls are blackened over with a thin layer of dull black paint—

(i) The total amount of heat lost by radiation to the walls of the vessel up to the moment of maximum pressure is roughly proportional to the

product of the third power of the maximum absolute temperature attained into the "time of explosion."

(ii) The total heat lost by radiation to the walls during explosion and subsequent cooling is about 25 per cent. of the heat of combustion of the gas present in the vessel.

(iii) The emission of radiation in the initial stages of cooling after explosion is a function of the time from ignition as well as of the temperature. The emission varies very rapidly with the temperature and the time from ignition.

(iv) In weak mixtures (and probably also in strong mixtures) the rate at which radiation is emitted is a maximum some time before the attainment of maximum pressure, and probably occurs at the moment when the flame fills the vessel.

(v) Weak mixtures radiate much more powerfully in the initial stages of cooling after explosion than stronger mixtures do when they have cooled to the same temperatures as the weaker mixtures have in this epoch.

(vi) Carbonic acid gas emits radiation about twice as strongly as an equal volume of water vapour at the same temperature does.

In explosions of mixtures of the same strength, but of various densities—

(vii) The total heat lost by radiation per cent. of the heat of combustion of the gas present in the vessel up to the moment of maximum pressure decreases as the intensity increases.

(viii) Denser mixtures emit radiation much more strongly than thinner mixtures—especially at the moment of maximum pressure and in the initial stages of cooling; the emission varies approximately as the square root of the density.

*Part II.*—The following results refer to experiments made in a vessel of the same dimensions, whose walls were silver plated, and therefore could be made reflecting or absorbent at will. The experiments were made with the bolometer placed at some distance behind the plate of fluorite, so that the emission was measured from a cone of gas of small solid angle.

(ix) The intrinsic radiance from a gaseous mixture at any given temperature after explosion depends largely on the reflecting power of the interior surface of the explosion vessel, and also on the size of the vessel. The greater the reflecting power, or the greater the size of the vessel, the greater the intrinsic radiance. This effect is probably due both to greater vibratory energy and to greater transparency of the gas in the larger vessels and in the reflecting vessels.

(x) (a) Gaseous mixtures, after explosion in a vessel with reflecting walls,

are very highly transparent to the radiation which they emit at maximum pressure and throughout cooling.

(b) Gaseous mixtures, after explosion in a vessel with black walls, are very highly transparent at the moment of maximum pressure, and also in the initial stages of cooling. Later on in the cooling they become fairly opaque.

[(xi)–(xiv) refer to coal-gas mixtures of the same strength but of different densities.]

(xi) The ratio of the intrinsic radiance from a definite thickness of gaseous mixtures of the same strength at any given temperature when the walls of the explosion vessel are reflecting to that when the walls are black decreases as the density increases.

(xii) When the walls of the explosion vessel are black, the transparency of a thickness of gas inversely proportional to the density at any given temperature increases as the density increases.

(xiii) (a) The intrinsic radiance from a definite thickness of gaseous mixture at any given temperature, after explosion in the vessel with black walls, varies as the square root of the density.

(b) The intrinsic radiance from thickness of gas inversely proportional to the density varies as the fourth root of the density.

(xiv) The intrinsic radiance corrected for absorption from  $1/D$  cm. of the gaseous mixtures at any given temperature in the vessel with black walls seems to decrease as the density ( $D$ ) increases.

(xv) The radiation (after correcting for absorption) from the hot gaseous mixture after explosion varies with the temperature approximately as Planck's formula for a single wave-length of  $3.6\mu$ ; this at high temperatures ( $1800^{\circ}$  C. to  $2400^{\circ}$  C. abs.) varies approximately as the square of the absolute temperature.

Many of the above results may be explained in terms of the following theory: A molecule, as it describes its free path, loses energy owing to the emission of radiation, and gains energy owing to the absorption of energy from the ether, and the vibratory energy of the molecule will increase or decrease according as the absorption is greater or less than the emission. During collision with another molecule, there will be a transference of energy between the vibratory energy and the rotational and translational energies, which, as Mr. Jeans has shown, will be very rapid if the duration of collision is comparable with the periods of vibration of the molecule. In the case of  $\text{CO}_2$  and steam at high temperatures, the duration of collision between the molecules is probably short in comparison with the periods of their low-frequency vibrations, and the vibratory energy of the molecules

will therefore tend to take up during collision a value such that the energy in each of the vibratory degrees of freedom equals that in each of the rotational and translational degrees. During collision, therefore, the vibratory energy of the molecules will tend to take up a value which is proportional to the absolute temperature, but, during the free path, there may be considerable departure from this value if the energy density in the ether is above or below a certain value, and the time of description of free path is not very short. The average value of the vibratory energy of the molecules will therefore depend not only upon the temperature of the gas, but also upon the value of the energy density in the ether, the rate at which the molecules emit radiation, the time of description of free path (inversely as the density of the gas), and the rate of partitioning of energy during collisions.

From result (iv) above, it is highly probable that the violence of combustion during explosion causes a considerable part of the energy of combustion to pass into the form of internal vibrations of the carbonic acid and steam molecules. Part of the energy in these vibrations is lost by radiation, but the greater part is transformed into rotational energy and translational or pressure energy.

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